CHARACTERISTICS OF MARTIAN VALLEY NETWORKS AND THE IMPLICATIONS FOR PAST CLIMATES.
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Introduction: Martian valley networks indicate that at least geologic conditions were different in the past, if not the climate. It is commonly believed that valley networks must be the result of groundwater sapping because their apparent drainage densities are lower than terrestrial runoff channels [1, 2, 3] (Figure 1a). It has also been suggested that valley networks are not uniformly distributed on topography, which would also argue in favor of groundwater sapping [4]. When coupled to the belief that early Mars was cold and dry such observations have led many investigators to suggest that valley networks were fed by geothermal heating of ground ice [4, 5, 6]. Unfortunately, however, plotting the densities of valley networks strictly from imagery data is easily influenced by observational bias and interpretation. To test some of the hypotheses derived from Viking era data, we have used MOLA topographic data and MOC and THEMIS imagery data to reevaluate valley network drainage densities and their related characteristics.

Approach: A number of algorithms have been written to allow investigators to extract terrestrial drainage basin information from digital elevation models (DEM's). In particular, the D8 algorithm is widely used (e.g., [7]) and is available in several GIS commercial software packages. At any given pixel flow direction is represented by a single angle taken as the steepest downward slope on the eight triangular facets center at each surrounding pixel. Upslope area is then calculated by proportioning flow between two downslope pixels according to how close this flow direction is to the downslope pixel. Flow direction is then integrated to determine the most probable flow paths for surface water over the given DEM. Streams of different magnitude are also identified following several conventions [8, 9, 10]. This information can then be used to characterize aspects of the drainage basin.

Mars Orbiter Laser Altimeter data collected from ±30° latitude were gridded to ~1 km resolution (Figure 1b). The resulting digital elevation models were then subjected to the D8 algorithm available through both RiverTools and Arc Hydro. Martian DEM's differ from terrestrial DEM's in that there is a great deal of topographic expression from impact craters that postdate the valley network systems. Complicating this is the fact that craters were also forming as the valley networks were developing. It appears that larger craters often changed the characteristics of the drainage basin completely [11]. Craters >20-km-diameter were treated as closed basins. Craters <20-km diameter were "filled in" to the surrounding base level so that they were essentially ignored by the algorithm. Gradients in flat areas were resolved using the imposed gradient method [12] so that flow direction remained self-consistent across these features. The resulting flow grid file was used to trace the location of valley networks (Figure 1c). These data were then compared to Viking orbiter and MOC photomosaics as well as available THEMIS images.

Results: Because impact craters are small, closed depressions with flat interiors, the D8 algorithm commonly produced spurious information inside many of these features (Figure 1c). However, there was excellent agreement between the D8 results and the location of valley networks in the surrounding highlands (Figure 1d). The results are consistent with valley networks identified from Viking images, yet the bias from image analyses alone becomes clear. Valley networks are much more complicated, integrated systems than have been previously reported [2, 3, 4]. Comparing the results to the imagery data suggest that there are three different types of valley network systems. The first is well defined and deeply incised, many of which have been identified before. Other valley networks are broader and typically flat floored. A third type is best described as "discontinuous" and poorly defined. Frequently such networks flow around knobs or mesas and appeared to have switched between confined and unconfined flow within short distances. Often all three types of valley networks are found within the same drainage basin. These observations suggest that valley network formation was a long-lived process that competed with other geologic processes, such as impact cratering and volcanic resurfacing, that were also pronounced in the early history of Mars. The drainage densities we calculated are a factor of 20 times higher than previous estimates (~0.193 km^{-1} versus 0.01 km^{-1} [3]), and are similar to densities for terrestrial runoff channels. There is also good agreement between drainage density and slope, arguing against suggestions that valley networks occur as isolated features or in clusters [4]. The simplest explanation for these observations is that the early martian climate must have supported precipitation and surface runoff.

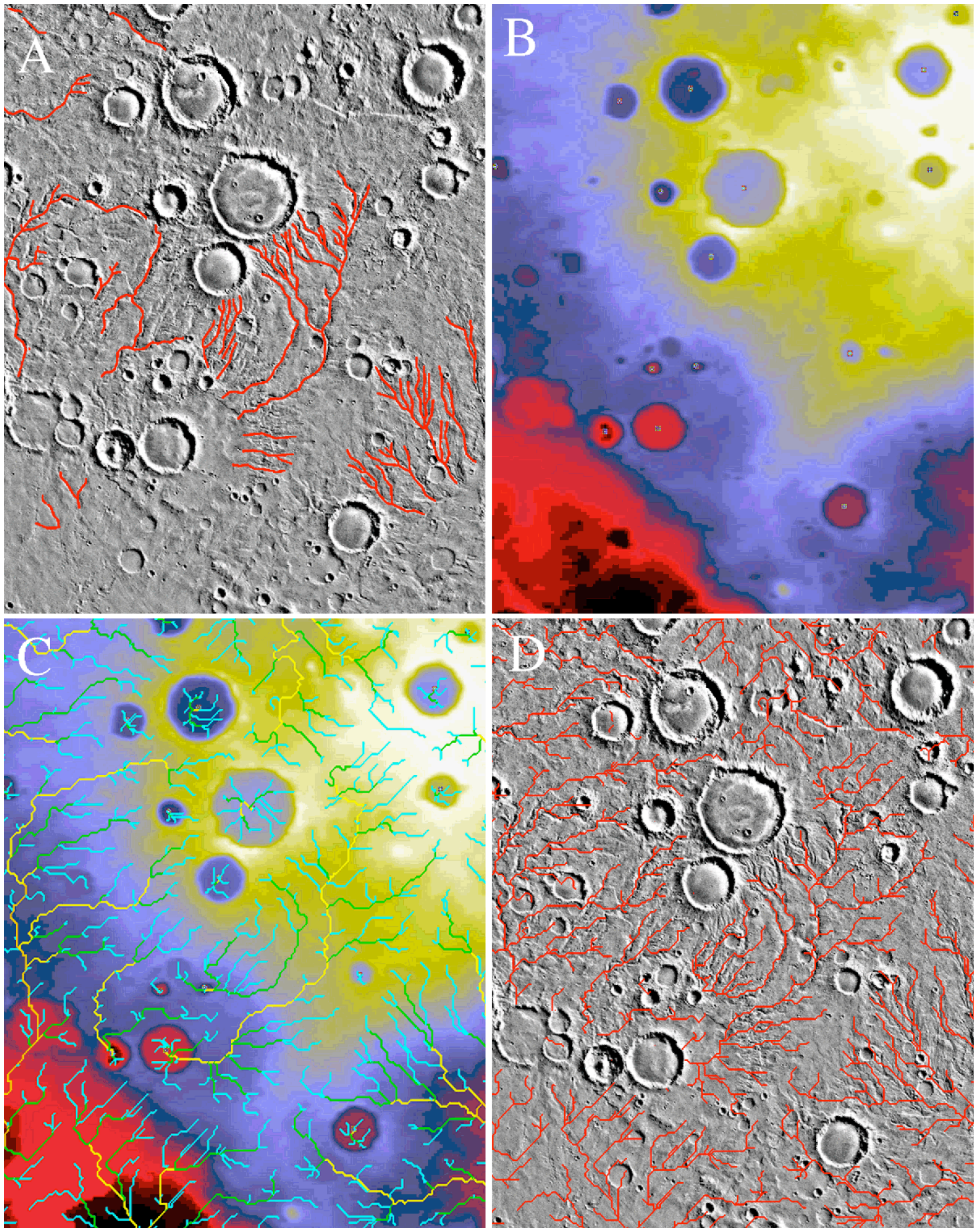

Figure 1. (A) An example of a martian drainage pattern derived from image analyses [3]. Arguably, many more valley networks are visible than have been plotted. (B) A MOLA DEM of the same area gridded at ~1 km resolution. (C) A plot of streams with Strahler orders ≥4 extracted from the D8 algorithm. (D) Results are plotted on a photomosaic base map where the results are checked. Compare with (A). Spurious data typically occurs in flat areas. Previously recognized valley networks are commonly part of larger, well-integrated networks.

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